(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 612 882 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 94103975.2

(22) Date of filing: 15.03.91

(51) Int. Cl.^{5}: D21F 1/00

This application was filed on 15 - 03 - 1994 as a divisional application to the application mentioned under INID code 60.

(30) Priority: 06.06.90 US 534164
15.08.90 US 567974
14.02.91 US 654008

(43) Date of publication of application:
31.08.94 Bulletin 94/35

(60) Publication number of the earlier application in accordance with Art.76 EPC: 0 532 510

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

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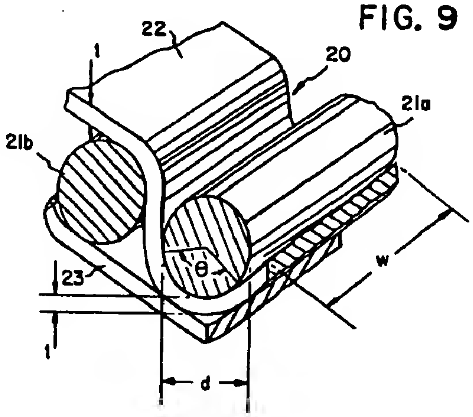
(54) Papermakers fabric with flat machine direction yarns.

(57) A papermakers fabric having a system of flat monofilament machine direction yarns 22,23 (hereinafter MD yarns) interwoven with a system of cross machine direction yarns 21a,21b (hereinafter CMD yarns). The MD yarns 22,23 have an aspect ratio of greater than 3:1. Furthermore the MD yarns are vertically stacked with at least paired upper 22 and lower 23 MD yarns which weave over and under CMD yarns 21a,21b in such a manner that when a lower MD yarn 23 weaves over a CMD yarn 21a an upper MD yarn 22 is weaving (or floating) over the lower MD yarn 23. This ensures that no knuckles are apparent on the upper surface of the fabric. The weave gives rise to a warp-fill in the range of 80-125%.

FIG. 9



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The present invention relates to papermakers fabrics and in particular to fabrics comprised of flat monofilament yarns.

BACKGROUND OF THE INVENTION

Papermaking machines generally are comprised of three sections: forming, pressing, and drying. Papermakers fabrics are employed to transport a continuous paper sheet through the papermaking equipment as the paper is being manufactured. The requirements and desirable characteristics of papermakers fabrics vary in accordance with the particular section of the machine where the respective fabrics are utilized.

With the development of synthetic yarns, shaped monofilament yarns have been employed in the construction of papermakers fabrics. For example, U.S. Patent No. 4,290,209 discloses a fabric woven of flat monofilament warp yarns; U.S. Patent No. 4,755,420 discloses a non-woven construction where the papermakers fabric is comprised of spirals made from flat monofilament yarns.

Numerous weaves are known in the art which are employed to achieve different results. For example, U.S. Patent No. 4,438,788 discloses a dryer fabric having three layers of cross machine direction yarns interwoven with a system of flat monofilament machine direction yarns such that floats are created on both the top and bottom surfaces of the fabric. The floats tend to provide a smooth surface for the fabric.

Permeability is an important criteria in the design of papermakers fabrics. In particular, with respect to fabrics made for running at high speeds on modern drying equipment, it is desirable to provide dryer fabrics with relatively low permeability.

U.S. Patent No. 4,290,209 discloses the use of flat monofilament warp yarns woven contiguous with each other to provide a fabric with reduced permeability. However, even where flat warp yarns are woven contiguous with each other, additional means, such as stuffer yarns, are required to reduce the permeability of the fabric. As pointed out in that patent, it is desirable to avoid the use of fluffy, bulky stuffer yarns to reduce permeability which make the fabric susceptible to picking up foreign substances or retaining water.

U.S. Patent No. 4,290,209 and U.S. Patent No. 4,755,420 note practical limitations in the aspect ratio (cross-sectional width to height ratio) of machine direction warp yarns defining the structural weave of a fabric. The highest practical aspect ratio disclosed in those patents is 3:1, and the aspect ratio is preferably, less than 2:1.

U.S. Patent No. 4,621,663, assigned to the assignee of the present invention, discloses one attempt to utilize high aspect ratio yarns (on the order of 5:1 and above) to define the surface of a papermakers dryer fabric. As disclosed in that patent, a woven base fabric is provided to support the high aspect ratio surface yarns. The woven base fabric is comprised of conventional round yarns and provides structural support and stability to the fabric disclosed in that patent.

U.S. Patent No. 4,815,499 discloses the use of flat yarns in the context of a forming fabric. That patent discloses a composite fabric comprised of an upper fabric and a lower fabric tied together by binder yarns. The aspect ratio employed for the flat machine direction yarns in both the upper and lower fabrics are well under 3:1.

In use, papermakers fabrics are configured as endless belts. Weaving techniques are available to initially weave fabrics endless. However, there are practical limitations on the overall size of endless woven fabrics as well as inherent installation difficulties. Moreover, not all papermaking equipment is designed to accept the installation of an endless fabric.

Flat woven fabrics are often supplied having opposing ends which are seamed together during installation of the fabric on papermaking equipment. Usually one end of the fabric is threaded through the serpentine path defined by the papermaking equipment and is then joined to its opposing end to form a continuous belt.

A variety of seaming techniques are well known in the art. One conventional method of seaming is to form the machine direction yarns on each end of the fabric into a series of loops. The loops of the respective fabric ends are then intermeshed during fabric installation to define a channel through which a pintle is inserted to lock the ends together.

For example, U.S. Patent Nos. 4,026,331; 4,438,789; 4,469,142; 4,846,231; 4,824,525 and 4,883,096 disclose a variety of pin seams wherein the machine direction yarns are utilized to form the end loops. In each of those patents, however, the machine direction yarn projects from the end of the fabric and weaves back into the fabric adjacent to itself. Accordingly, the loops inherently have a twist or torque factor and are not entirely orthogonal to the plane of the fabric. U.S. Patent 4,883,096 specifically addresses this problem.

It would be desirable to provide a papermakers fabric with machine direction seaming loops which do not have torque and/or twist.

SUMMARY AND OBJECTS INVENTION

The present invention provides a papermakers fabric having a system of flat monofilament machine direction yarns (hereinafter MD yarns) which are stacked to control the permeability of the fabric. The present weave also provides for usage of high aspect ratio yarns as structural weave components. The system of MD yarns comprises upper and lower yarns which are vertically stacked. Preferably, the upper MD yarns define floats on the upper surface of the fabric and each upper MD yarn is paired in a vertically stacked orientation with a lower MD yarn. The lower MD yams may weave in an inverted image of the upper MD yarns to provide floats on the bottom fabric surface or may weave with a different repeat to provide a different surface on the bottom of the fabric.

At least the upper MD yarns are flat monofilament yarns woven contiguous with each other to reduce the permeability of the fabric and to lock in the machine direction alignment of the stacking pairs of MD yarns. In the preferred embodiment, the same type and size yarns are used throughout the machine direction yarn system and both the top and the bottom MD yarns weave contiguously with adjacent top and bottom MD yarns, respectively. The stacked, contiguous woven machine direction system provides stability and permits the MD yarns to have a relatively high aspect ratio, cross-sectional width to height, of greater than 3:1.; the aspect ratio preferably ranging from about 2:1 to 6:1. machine direction yarns further define a series of orthogonal seaming loops on the opposing fabric ends. End segments of the lower MD yarns are removed and the upper MD yarn ends are looped back upon themselves and rewoven into the fabric end in the space vacated by the trimmed lower MD yarn end segments. The lower MD yarns may weave in an inverted image of the upper MD yarns such that the crimp of the upper MD yarns conforms with the lower MD yarn weave pattern space into which the upper MD yarn ends are backwoven. This improves the strength of the seam.

Non-loop forming upper MD yarns are also preferably backwoven into the space vacated by trimming the respective lower MD yarns. Preferably, at least the upper MD yarns are woven contiguous with each other to lock in the machine direction alignment of the stacking pairs of MD yams and the orthogonal orientation of the end loops. In the preferred embodiment, the same type of material and the same geometric shape and size yarns are used throughout the machine direction yarn system and both the top and the bottom MD yams weave contiguously with adjacent top and bottom MD yams, respectively.

It is an object of the invention to provide a papermakers fabrics having permeability controlled with woven flat machine direction yarns.

It is a further object of the invention to provide a low permeability fabric constructed of all monofilament yarns without the use of bulky stuffer yams and without sacrificing strength or stability.

Other objects and advantages will become apparent from the following description of presently preferred embodiments.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a schematic diagram of a papermakers fabric made in accordance with the teachings of the present invention;

Figure 2 is a cross-sectional view of the fabric depicted in Figure 1 along line 2-2;

Figure 3a is a cross-sectional view of the fabric depicted in Figure 1 along line 3-3;

Figure 3b is a cross-sectional view of a prior art weave construction;

Figure 4a illustrates the yarn orientation in the fabric depicted in Figure 1 after the fabric is finished showing only two representative stacked MD yarns;

Figures 4b, 4c, and 4d are a series of illustrations showing the formation of a seaming loop for the papermakers fabric depicted in Figure 1;

Figure 5a is a perspective view of a prior art MD yarn seaming loop;

Figure 5b is a perspective view of an orthogonal MD yarn seaming loop made in accordance with the present invention;

Figure 6 is a schematic view of a second embodiment of a fabric made in accordance with the present invention;

Figure 7 is a cross-sectional view of the fabric depicted in Figure 6 along line 7-7;

Figure 8 is a cross-sectional view of the fabric depicted in Figure 6 along line 8-8;

Figure 9 is a perspective view of a portion of the fabric illustrated in Figures 6-8;

Figure 10 illustrates the yarn orientation in the finished fabric depicted in Figure 6 showing the end loop formed by one of the MD yarns;

Figure 11 is a top view of the opposing ends of a fabric constructed in accordance with Figure 6 just prior to pin-seaming the ends together;

Figure 12 is a schematic view of a third alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

Figure 13 is a schematic view of a fourth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

Figure 14 is a schematic view of a fifth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

Figure 15 is a schematic view of a sixth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

Figure 16 is a schematic view of a seventh alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns; and

Figure 17 is a schematic view of a eighth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns.

DETAILED DESCRIPTION OF PRESENTLY PREFERRED EMBODIMENTS

Referring to Figures 1, 2, and 3a, there is shown a papermakers dryer fabric 10 comprising upper, middle and lower layers of cross machine direction (hereinafter CMD) yarns 11, 12, 13, respectively, interwoven with a system of MD yarns 14-19 which sequentially weave in a selected repeat pattern. The MD yarn system comprises upper MD yarns 14, 16, 18 which interweave with CMD yarns 11, 12 and lower MD yarns 15, 17, 19 which interweave with CMD yarns 12, 13.

The upper MD yarns 14, 16, 18 define floats on the top surface of the fabric 10 by weaving over two upper layer CMD yarns 11 dropping into the fabric to weave in an interior knuckle under one middle layer CMD yarn 12 and under one CMD yarn 11 and thereafter rising to the surface of the fabric to continue the repeat of the yarn. The floats over upper layer CMD yarns 11 of upper MD yarns 14, 16, 18 are staggered so that all of the upper and middle layer CMD yarns 11, 12 are maintained in the weave.

As will be recognized by those skilled in the art, the disclosed weave pattern with respect to Figures 1, 2, and 3a, results in the top surface of the fabric having a twill pattern. Although the two-float twill pattern represented in Figures 1, 2, and 3a is a preferred embodiment, it will be recognized by those of ordinary skill in the art that the length of the float, the number of MD yarns in the repeat, and the ordering of the MD yarns may be selected as desired so that other patterns, twill or non-twill, are produced.

As best seen in Figures 2 and 3a, lower MD yarns 15, 17, 19, weave directly beneath upper MD yarns 14, 16, 18, respectively, in a vertically stacked relationship. The lower yarns weave in an inverted image of their respective upper yarns. Each lower MD yarn 15, 17, 19 floats under two lower layer CMD yarns 13, rises into the fabric over one CMD yarn 13 and forms a knuckle around one middle layer CMD yarn 12 whereafter the yarn returns to the lower fabric surface to continue its repeat floating under the next two lower layer CMD yarns 13.

With respect to each pair of stacked yarns, the interior knuckle, formed around the middle layer CMD yarns 12 by one MD yarn, is hidden by the float of the other MD yarn. For example, in Figures 1 and 3a, lower MD yarn 15 is depicted weaving a knuckle over CMD yarn 12 while MD yarn 14 is weaving its float over CMD yarns 11, thereby hiding the interior knuckle of lower MD yarn 15. Likewise, with respect to Figures 1 and 3a, upper MD yarn 18 is depicted weaving a knuckle under yarn CMD yarn 12 while it is hidden by lower MD yarn 19 as it floats under CMD yarns 13.

The upper MD yarns 14, 16, 18, are woven contiguous with respect to each other. This maintains their respective parallel machine direction alignment and reduces permeability. Such close weaving of machine direction yarns is known in the art as 100% warp fill as explained in U.S. Patent No. 4,290,209. As taught therein (and used herein), actual warp count in a woven fabric may vary between about 80%-125% in a single layer and still be considered 100% warp fill.

The crowding of MD yarns 14, 16, and 18 also serves to force MD yarns 15, 17, 19, into their stacked position beneath respective MD yarns 14, 16, 18. Preferably MD yarns 15, 17, and 19 are the same size as MD yarns 14, 16, and 18 so that they are likewise woven 100% warp fill. This results in the overall fabric of the preferred embodiment having 200% warp fill of MD yarns.

Since the lower MD yarns 15, 17, 19 are also preferably woven 100% warp fill, they likewise have the effect of maintaining the upper MD yarns 14, 16, 18 in stacked relationship with the respect to lower MD yarns 15, 17, 19. Accordingly, the respective MD yarn pairs 14 and 15, 16 and 17, 18 and 19 are doubly locked into position thereby enhancing the stability of the fabric.

As set forth in the U.S. Patent No. 4,290,209, it has been recognized that machine direction flat yarns will weave in closer contact around cross machine direction yarns than round yarns. However, a 3:1 aspect ratio was viewed as a practical limit for such woven yarns in order to preserve overall fabric stability. The present stacked MD yarn system preserves the stability and machine direction strength of the fabric and enables the usage of yarns with increased aspect ratio, in a preferred range of 2:1 to 6:1, to more effectively control permeability.

The high aspect ratio of the MD yarns translates into reduced permeability. High aspect ratio yarns are wider and thinner than conventional flat yarns which have aspect ratios less than 3:1 and the same cross-sectional area. Equal cross-sectional area means that comparable yarns have substantially the same linear strength. The greater width of the high aspect ratio yarns translates into fewer interstices over the width of the fabric than with conventional yarns so that fewer openings exist in the fabric through which fluids may flow. The relative thinness of the high aspect ratio yarns enables the flat MD yarns to more efficiently cradle, i.e. brace, the cross machine direction yarns to reduce the size of the interstices between machine direction and cross machine direction yarns.

For example, as illustrated in Figure 3b, a fabric woven with a single layer system of a flat machine direction warp having a cross-sectional width of 1.5 units and a cross-sectional height of 1 unit, i.e. an aspect ratio of 1.5:1, is shown. Such fabric could be replaced by a fabric having the present dual stacked MD yarn system with MD yarns which are twice the width, i.e. 3 units, and half the height, i.e. 0.5 units. Such MD yarns thusly having a fourfold greater aspect ratio of 6:1, as illustrated in Figure 3a.

The thinner, wider MD yarns more efficiently control permeability while the machine direction strength of the fabric remains essentially unaltered since the cross-sectional area of the MD yarns over the width of the fabric remains the same. For the above example, illustrated by Figures 3a and 3b, the conventional single MD yarn system fabric has six conventional contiguous flat yarns over 9 units of the fabric width having a cross-sectional area of 9 square units, i.e. 6*(1u.*1.5u.). The thinner, wider high aspect ratio yarns, woven as contiguous stacked MD yarns, define a fabric which has three stacked pairs of MD yarns over 9 units of fabric width. Thus such fabric also has a cross-sectional area of 9 square units, i.e. (3*(0.5u.*3u.)) + (3*(0.5u.*3u.)), over 9 units of fabric width.

In one example, a fabric was woven in accordance with Figures 1, 2 and 3, wherein the CMD yarns 11, 12, 13 were polyester monofilament yarns 0.6mm in diameter interwoven with MD yarns 14-19 which were flat polyester monofilament yarns having a width of 1.12mm and a height of 0.2mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 48 warp ends per inch with a loom tension of 40 PLI (pounds per linear inch) and 12.5 CMD pick yarns per inch per layer (three layers).

The fabric was heat set in a conventional heat setting apparatus under conditions of temperature, tension and time within known ranges for polyester monofilament yarns. For example, conventional polyester fabrics are heat set within parameters of 340°F-380°F temperature, 6-15 PLI (pounds per linear inch) tension, and 3-4 minutes time. However, due to their stable structure, the fabrics of the present invention are more tolerant to variations in heat setting parameters.

The fabric exhibited a warp modulus of 6000 PSI (pounds per square inch) measured by the ASTM D-1682-64 standard of the American Society for Testing and Materials. The fabric stretched less that 0.2% in length during heat setting. This result renders the manufacture of fabrics in accordance with the teachings of the present invention very reliable in achieving desired dimensional characteristic as compared to conventional fabrics.

The resultant heat set fabric had 12.5 CMD yarns per inch per layer with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric has a permeability of 83CFM as measured by the ASTM D-737-75 standard.

As illustrated in Figure 4a, when the fabric 10 is woven the three layers of CMD yarns 11, 12, 13 become compressed. This compression along with the relatively thin dimension of the MD yarns reduces the caliper of the fabric. Accordingly, the overall caliper of the fabric can be maintained relatively low and not significantly greater than conventional fabrics woven without stacked MD yarn pairs. In the above example, the caliper of the finished fabric was 0.050 inches.

It will be recognized by those of ordinary skill in the art that if either top MD yarns 14, 16, 18 or bottom MD yarns 15, 17, 19 are woven at 100% warp fill, the overall warp fill for the stacked fabric will be significantly greater than 100% which will contribute to the reduction of permeability of the fabric. The instant fabric having stacked MD yarns will be recognized as having a significantly greater percentage of a warp fill than fabrics which have an actual warp fill of 125% of non-stacked MD yarns brought about by crowding and lateral undulation of the warp strands. Although the 200% warp fill is preferred, a fabric may be woven having 100% fill for either the upper or lower MD yarns with a lesser degree of fill for the other MD yarns by utilizing yarns which are not as wide as those MD yarns woven at 100% warp fill. For example, upper yarns 14, 16, 18 could be 1 unit wide with lower layer yarns 15, 17, 19 being .75 units wide which would result in a fabric having approximately 175% warp fill.

Such variations can be used to achieve a selected degree of permeability. Alternatively, such variations could be employed to make a forming fabric. In such a case, the lower MD yarns would be woven 100% warp fill to define the machine side of the fabric and the upper MD yarns would

be woven at a substantially lower percentage of fill to provide a more open paper forming surface.

The stacked pair MD weave permits the formation of orthogonal seaming loops within MD yarns. With reference to Figures 4a-d, after the fabric has been woven and heat set (Figure 4a), CMD yarns are removed leaving the crimped MD yarns 14, 15 exposed (Figure 4b). One of the yarns, for example, MD lower yarn 15, of the stacked pair is trimmed back a selected distance leaving the other exposed MD yarn 14 of the MD yarn pair and vacated space between the CMD yarns, as illustrated in Figure 4c. Upper MD yarn 14 is then backwoven into the space vacated in the weave pattern by lower MD yarn 15 such that a loop L is formed on the end of the fabric, as illustrated in Figure 4d. Preferably, between 0.5 - 5.0 inches of upper layer yarn 14 is backwoven into the fabric to provide sufficient strength for the end loop and assure retention of the free end of MD yarn 14 within the weave of the fabric. The inverted image weave permits the crimp of the upper MD yarn 14 to match the space vacated by the lower MD yarn 15 which further enhances the strength of the end loop.

As shown in phantom in Figure 4d, adjacent yarn pair 16, 17 is processed in a similar manner. However, when upper yarn 16 is looped back and backwoven in the fabric, it is pulled against the CMD yarns. In the preferred embodiment, wherein the upper MD yarns are woven 100% fill, the crowding of the yarns secure the orthogonal orientation of the seaming loops.

To achieve a uniform seam for a fabric woven in accordance with the weave pattern depicted in Figure 1, each upper MD yarn 14 forms a loop and the other upper MD yarns 16, 18 are backwoven against the endmost CMD yarn of the fabric. Thus every third upper MD yarn defines a loop such that an array of loops is created on each end of the fabric. The seam is assembled by intermeshing the opposing arrays of loops and inserting a pintle yarn between the interneshed loops.

Preferably, loop forming yarns 14 would all be backwoven approximately the same distance within the fabric to provide sufficient strength to prevent the loops from being pulled apart during normal usage. Non-loop forming yarns 16, 18, would preferably be backwoven a somewhat shorter distance since during usage no load is imparted to those yarns. For example, upper MD yarns 14 would be backwoven approximately 3 inches, MD yarns 16 would be backwoven approximately 2 inches, and MD yarns 18 would be backwoven approximately 1 inch. Respective lower layer yarns 15, 17, 19 would be trimmed to complement the backweaving of their respective MD yarn pair yarns 14, 16, 18.

Figures 5a and 5b, respectively, illustrate a conventional seaming loop 50 in comparison with an orthogonal seaming loop L of the present invention. In conventional loop forming techniques, the MD yarn 51 is backwoven into the fabric adjacent to itself thereby inherently imparting twist and/or torque to the loop structure 50. In the present invention, the MD yarn is looped directly beneath itself and does not have any lateral offset which would impart such twist or torque to the seaming loop.

Referring to Figures 6, 7 and 8, there is shown a second preferred embodiment of a fabric 20 made in accordance with the teachings of the present invention. Papermakers fabric 20 is comprised of a single layer of CMD yarns 21a, 21b interwoven with a system of stacked MD yarns 22-25 which weave in a selected repeat pattern. The MD yarn system comprises upper MD yarns 22, 24 which define floats on the top surface of the fabric 20 by weaving over three CMD yarns, under the next one CMD yarn 21a to form a knuckle, and thereafter returning to float over the next three CMD yarns in a continuation of the repeat.

Lower MD yarns 23, 25, weave directly beneath respective upper MD yarns 22, 24 in a vertically stacked relationship. The lower MD yarns weave in an inverted image of their respective upper MD yarns. Each lower MD yarn 23, 25 floats under three CMD yarns, weaves upwardly around the next one CMD yarn 21a forming a knuckle and thereafter continues in the repeat to float under the next three CMD yarns.

As can be seen with respect to Figures 6 and 8, the knuckles formed by the lower MD yarns 23, 25 are hidden by the floats defined by the upper MD yarns 22, 24 respectively. Likewise the knuckles formed by the upper MD yarns 22, 24 are hidden by the floats of the lower MD yarns 23, 25 respectively.

The caliper of the fabric proximate the knuckle area shown in Figure 8, has a tendency to be somewhat greater than the caliper of the fabric at non-knuckle CMD yarns 21b, shown in Figure 7. However, the CMD yarns 21a around which the knuckles are formed become crimped which reduces the caliper of the fabric in that area as illustrated in Figure 8. Additionally, slightly larger diameter CMD yarns are preferably used for CMD yarns 21b, shown in Figure 7, which are not woven around as knuckles by the MD yarns to eliminate any difference in fabric caliber. Preferably the diameter of the larger CMD yarn 21b equals the diameter d of the smaller CMD yarns 21a plus the thickness t of the MD yarns.

In one example, a fabric was woven in accordance with Figures 6-9, wherein the CMD yarns 21a, 21b were polyester monofilament yarns

0.6mm and 0.8mm, respectively, in diameter interwoven with MD yarns 22-25 which were flat polyester monofilament yarns having a width of 1.12mm and a height of 0.2mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 48 total warp ends per inch with a loom tension of 40 PLI (pounds per linear inch) and 20 CMD total pick yarns per inch. The permeability averaged 90 CFM in the resultant fabric.

In another example, fabric was woven in accordance with Figures 6, 7 and 8, wherein the CMD yarns 21a, 21b were polyester monofilament yarns 0.7mm in diameter interwoven with MD yarns 22-25 which were flat polyester monofilament yarns having a width of 1.12mm and a height of 0.2mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 22 CMD pick yarns per inch. The fabric was heat set using conventional methods. The fabric exhibited a modulus of 6000 PSI. The fabric stretched less than 0.2% in length during heat setting. The resultant fabric had 22 CMD yarns per inch with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric had a caliper of .048 inches and an air permeability of 60CFM.

As best shown in Figure 9, the high aspect ratio yarns 22-24 effectively brace the CMD yarns 21a in the weave construction. This bracing effect can be quantified in terms of the degree of contact arc θ and contact bracing area, CBA, as follows:

$$CBA = \pi d \left(\frac{\theta}{360^\circ}\right) w$$

where

- d = diameter of the CMD yarn
- θ = the degree of arc over which there is contact between the MD and CMD yarns
- w = width of the MD yarn
- π = the constant pi.

The degrees of arc over which MD yarns 22-25 are in contact with CMD yarns 21a is dependent upon the spacing of the CMD yarns within the weave. For the above example, employing alternating 0.6mm and 0.8mm diameter CMD yarns with 0.2mm thick MD yarns, the degree of contact arc can be maintained in a preferred range of between 60° to 180° by varying the pick count of the CMD yarns from 14 picks per inch to a maximum of 28.22 picks per inch.

In the preferred embodiment where the pick count is 20 picks per inch, the degree of contact arc θ is approximately 101°. This results in a bracing contact area of approximately 0.79mm^2 at each knuckle in the fabric.

Applicant's use of high ratio aspect yarns, i.e. yarns having a width:thickness ratio of at least 3:1, provides for increased bracing contact of the flat MD yarns with the CMD yarns 21a. This is comparatively exemplified by modifying the equation for contact bracing area, CBA, to be defined in terms of the thickness of the MD yarns.

Since the MD yarn width w equals the thickness t of the MD yarn multiplied by the aspect ratio, $w > 3t$ for yarns having an aspect ratio greater than 3:1. Accordingly, fabrics made in accordance with the teachings of the present invention utilizing high aspect ratio MD yarns exhibit enhanced bracing of the CMD yarns by the MD yarns such that:

$$CBA > \pi d \left(\frac{\theta}{360^\circ}\right) 3t.$$

As best seen in Figure 10, seaming loops are formed by upper MD yarns 22. The respective lower MD yarns 23 are trimmed a selected distance from the fabric end and the upper MD yarns 22 are backwoven into the space vacated by the trimmed lower MD yarns 23.

Upper MD yarns 24 are similarly backwoven into the space vacated by trimming back lower MD yarns 25. However, as best seen in Figure 10, upper MD yarns 24 are backwoven against the madness CMD yarn 21b.

As illustrated in Figure 11, a series of seaming loops is formed on each of the opposing fabric ends 27, 28. When the fabric is installed on papermaking equipment, the respective end loops formed by MD yarns 22 are intermeshed and a pintle 30 is inserted therethrough to lock the intermeshed series of loops together.

Since the seaming loops L are formed by backweaving MD yarns 22 directly beneath themselves, no lateral twist or torque is imparted on the loop and the loops are orthogonal with the plane of the fabric. This facilitates the intermeshing of the loop series of the opposing fabric ends 27, 28. The orthogonal loops are particularly advantageous where, as shown in Figure 10, the MD yarns 22, 24 are 100% warp fill and adjacent loops are separated by individual MD yarns of the same width as the loop MD yarns 22. Lateral torque or twist on the seaming loops make the seaming process more difficult particularly where the loop-receiving gaps between the loops of one fabric end are essentially the same width as the loops on the opposing fabric end and vice versa.

With reference to the fabric depicted in Figures 6-11, the loop forming MD yarns 22 are preferably backwoven approximately 2 inches while the non-loop forming MD yarns 24 are preferably back-

woven 1 inch.

With reference to Figure 12, a third embodiment of a papermakers fabric 30 is shown. Fabric 30 comprises a single layer of CMD yarns 31 interwoven with stacked pairs of flat monofilament yarns in a selected repeat pattern. For clarity, only one pair of stacked MD yarns is shown comprising upper MD yarn 32 and lower MD yarn 33. The upper MD yarns weave in a float over two CMD yarns 31, form a single knuckle under the next CMD yarn 31 and thereafter repeat. Similarly the lower MD yarns weave in an inverted image of the upper MD yarns weaving under two CMD yarns 31, forming a knuckle over the next CMD yarn 31 and then returning to the bottom surface of the fabric in the repeat. Since the repeat of both the upper and lower MD yarns is with respect to three CMD yarns 31, a total of three different stacked pairs of yarns comprise the weave pattern of the MD yarn system.

A fabric was woven in accordance with Figure 12 wherein the CMD yarns 31 were polyester monofilament yarns 0.7mm in diameter interwoven with MD yarns which were flat polyester monofilament yarns having a width of 1.12mm and a height of 0.2mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven 48 warp ends per inch under a loom tension of 60 PLI and 18 CMD pick yarns per inch. The fabric was heat set using conventional methods. The fabric exhibited amodulus of 6000 PSI. The fabric stretched less than 0.2% in length during heat setting. The resultant fabric had 18 CMD yarns per inch with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric having a caliper of 0.046 inches and an air permeability of 66CFM.

With reference to Figure 13, a fourth embodiment of a papermakers fabric 40 is shown. Fabric 40 comprises upper, middle and lower layers of CMD yarns 41, 42, 43, respectively, interwoven with stacked pairs of flat monofilament yarns in a selected repeat pattern. For clarity, only one pair of stacked MD yarns is shown comprising upper MD yarn 44 and lower MD yarn 45. The upper MD yarns weave in a float over two upper layer CMD yarns 41, under the next yarn 41 and a middle layer yarn 42 to form a single knuckle, under the next CMD yarn 41 and thereafter rise to the top surface to continue to repeat. Similarly, the lower MD yarns weave in an inverted image of the upper MD yarns weaving under two lower layer CMD yarns 43 over the next CMD yarn 43 and a middle CMD yarn 42 forming a knuckle, over the next CMD yarn 43 then returning to the bottom surface of the fabric to repeat. Since the repeat of both the upper and lower MD yarns is with respect to four upper and lower CMD yarns 41, 43, respectively, a total of four different stacked pairs of yarns comprise the weave pattern of the MD yarn system.

A fabric was woven in accordance with Figure 13, wherein the upper and lower layer CMD yarns 41, 43 were nylon-sheathed, multifilament polyester yarns 0.62mm in diameter and the middle layer CMD yarns 42 were polyester monofilament yarns 0.5mm in diameter interwoven with MD yarns 22-25 which were flat polyester monofilament yarns having a width of 0.60mm and a height of 0.38mm. Accordingly, the aspect ratio of the flat MD yarns was 1.58:1. The fabric was woven with 96 warp ends per inch under a loom tension of 40 PLI and 15 CMD pick yarns per inch per layer. The fabric was heat set using conventional methods. The resultant fabric had 15 CMD yarns per inch per layer with 113% MD warp fill with respect to both upper and lower MD yarns resulting in 226% actual warp fill for the fabric. The finished fabric had a caliper of .075 inches and an air permeability of 60CFM.

Figures 14, 15 and 16 illustrate the fifth, sixth and seventh embodiments of the present invention. Figure 14 illustrates the weave of a relatively long float on both sides of the fabric; Figure 15 illustrates how a stacked pair MD yarn weave can define floats of different lengths on opposite sides of the fabric; and Figure 16 illustrates how a stacked pair MD yarn weave can be used to construct fabrics having MD knuckles on one side of the fabric.

Relatively long floats predominating the surfaces of a dryer fabric are beneficial for both the paper-carrying side as well as the machine side of the fabric. On the paper-carrying side, long floats provide greater contact area with the paper sheet for increased heat transfer. On the machine side, long floats provide increased wear surface and contact area to reduce bounce and flutter. The stacked pair MD yarn weave is versatile in allowing different surfaces to be defined on the top and bottom sides of the fabric. Accordingly, fabrics made in accordance with the teachings of the present invention may be used for other industrial purposes such as in the drying of sludge.

With respect to Figure 14, a fabric 50 is illustrated comprising three layers of yarns 51, 52, and 53 respectively. In this construction, the MD yarn pairs, such as the pair formed by upper layer yarn 54 and lower layer yarn 55, define relatively long floats on both the top and bottom surfaces of the fabric. Upper yarn 54 weaves over five upper layer CMD yarns 51, drops into the fabric to form a knuckle under one middle layer CMD yarn 52, weaves under the next upper layer yarn 51 and thereafter repeats. Lower MD yarn 55 weaves in an inverted image under five lower layer CMD yarns 53, rising into the fabric over the next CMD 53 to weave a knuckle over one middle layer CMD yarn

52 thereafter dropping to the bottom surface of the fabric to continue its repeat. In such a construction, six pairs of stacked MD yarns are utilized in the repeat of the fabric and are sequentially woven in a selected sequence to produce a desired pattern on the surfaces of the fabric which will be predominated by the MD yarn floats.

The embodiment shown in Figure 15 depicts a fabric 60 in which the MD yarns weave with a five-float repeat on the top fabric surface and a two-float repeat on the bottom fabric surface. For example, upper MD yarn 64 interweaves with upper and middle CMD yarns 61, 62 in the same manner that upper MD yarn 54 weaves with respective CMD yarns 51, 52 with respect to fabric 50 in Figure 14. However, lower MD yarn 65, which forms a stacked pair with upper MD yarn 64, weaves in a two-float bottom repeat with respect lower and middle CMD yarns 63, 62. For example, lower MD yarn 65 floats under two lower layer CMD yarns 63, rises above the next CMD yarn 63 to form a knuckle over one middle layer CMD yarn 62 and thereafter drops to the bottom surface of the fabric 60 to continue to repeat. As with the other embodiments discussed above, the interior knuckles formed by the lower MD yarns are hidden by the upper MD yarn of the respective stacked pair and vice-versa.

The construction shown in Figure 15 permits different surfaces to be defined on the top and bottom of the fabric while utilizing the benefits of the stacked MD yarn pairing.

The embodiment shown in Figure 16 discloses another example of a fabric 70 having five-float MD yarns predominating the upper surface of the fabric, but with MD knuckles on the lower surface of the fabric. This type of construction may be advantageously used to construct a forming fabric where the upper fabric surface, having relatively long floats, would be used as the machine side of the fabric and the knuckled lower surface of the fabric would be used as the paper forming side.

Fabric 70 includes three layers of CMD yarns 71, 72, 73 respectively which interweave with stacked pairs of MD yarns to define this construction. Only one pair of stacked pair of MD yarns 74, 75 is depicted for clarity. Upper MD yarn 74 weaves in a five-float pattern with respect to upper and middle layer CMD yarns 71, 72 in the same manner as upper MD yarn 54 with respect to fabric 50 shown in Figure 14. Lower MD yarn 75 weaves three interior knuckles and three lower surface knuckles with respect to middle and lower layer CMD yarns 72, 73 under each upper surface float of its respective MD yarn pair yarn 74. The repeat of the upper MD yarns is defined with respect to six upper layer CMD yarns 71 and the repeat of the lower MD yarns is defined with respect to only two lower layer CMD yarns 73. Accordingly, there are six different pairs of stacked MD yarns which constitute the MD yarn system which, as noted above, can be arranged such that a desired pattern is formed on the upper surface of the fabric.

Generally for stacked pair weaves, the repeat of the upper MD yarns will be equally divisible by, or an equal multiple of, the repeat of the lower MD yarns in defining the stacking pair relationship. For example, with respect to Figure 12 the repeat of the upper MD yarns is six upper layer CMD yarns which is equally divisible by the repeat of the lower MD yarns which is three lower layer CMD yarns.

With respect to the eighth alternate embodiment shown in Figure 17, a fabric 80 is illustrated having a single layer of CMD yarns 81 and a representative stacked pair of MD yarns 82, 83. Upper MD yarn 82 weaves with two floats over CMD yarns 81 with a repeat occurring with respect to three CMD yarns 81. Lower MD yarn 83 weaves with five floats under CMD yarns 81 with a repeat of six CMD yarns 81. Thus, in fabric 80, the repeat of the upper MD yarns, which is three, is an equal multiple of the repeat of lower MD yarns, which is six.

A variety of other weave patterns employing the paired stacked weave construction of the instant invention may be constructed within the scope of the present invention. For example, in some applications it may be desirable to have MD yarn surface floats over six or more CMD yarns. Such fabrics are readily constructed in accordance with the teachings of the present invention.

Claims

1. A papermakers fabric comprising a system of CMD yarns interwoven with a system of flat monofilament MD yarns as structural weave components in a selected repeat pattern characterised in that said MD yarns consist essentially of yarns having an aspect ratio greater than 3:1.

2. A papermakers fabric according to claim 1 wherein said MD yarns comprise pairs of upper and lower MD yarns stacked in vertical alignment and the actual warp fill of at least said upper MD yarns is in the range of 80% - 125%.

3. A papermakers fabric according to claim 1 wherein said CMD yarn system further includes an upper, middle and lower layer of CMD yarns and wherein said MD yarns interweave with said middle layer CMD yarns with hidden interior knuckles; said upper MD yarns interweaving with said upper and middle layer CMD yarns, and said lower MD yarns inter-

weaving with said lower and middle layer CMD yarns.

4. A papermakers fabric according to claim 1 wherein said fabric consists essentially of all monofilament yarns.

5. A papermakers fabric according to claim 1 wherein said CMD yarn system comprises a single layer of CMD yarns and wherein said MD yarns interweave with said single layer of CMD yarns with hidden interior knuckles.

6. A papermakers fabric comprising a system of flat MD yarns having a thickness t interwoven with a system of CMD yarns characterised in that:

said MD yarns are woven with selected CMD yarns having a diameter d in bracing contact over a contact arc of Θ degrees such that the contact bracing area CBA of the MD yarn interweavings with said selected CMD yarns is related to the degree of contact arc Θ as follows:

$$CBA > \pi d \left(\frac{\Theta}{360^\circ}\right) 3t.$$

7. A papermakers fabric according to claim 6 wherein Θ is at least 60° and t is about 0.2mm.

8. A papermakers fabric according to claim 6 wherein said fabric consists essentially of all monofilament yarns.

9. A papermakers fabric according to claim 6 wherein Θ is about 101°.

10. A papermakers fabric according to claim 6 wherein the average permeability over the fabric is 90 CFM.

11. A papermakers fabric according to claim 10 wherein the range of permeability is 87-93 CFM.

12. A papermakers fabric according to claim 6 wherein the CMD yarn system is a single layer of CMD yarns.

13. A papermakers fabric according to claim 12 wherein said MD yarns interweave with knuckles only with alternate CMD yarns of said single CMD yarn layer, said alternate CMD yarns being said selected CMD yarns.

14. A papermakers fabric according to claim 13 wherein the diameter of the alternate non-selected CMD yarns is about t + d.

15. A papermakers fabric according to claim 13 wherein t is about 0.2mm, d is about 0.6mm, the diameter of the alternate non-selected CMD yarns is about 0.8mm and Θ is about 101°.

16. A papermakers fabric according to claim 15 wherein the average permeability over the fabric is 90 CFM.

17. A papermakers fabric according to claim 16 wherein the range of permeability is 87-93 CFM.

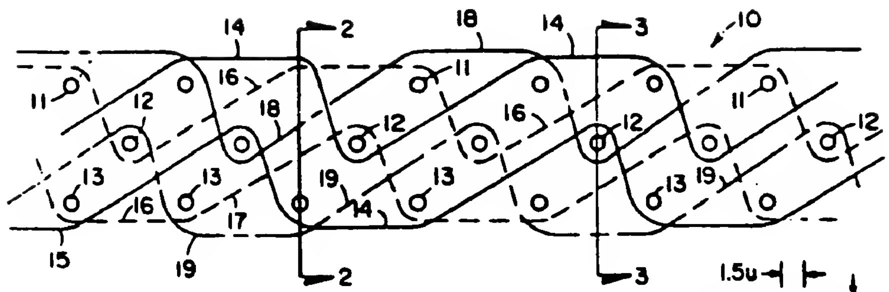


FIG. 1

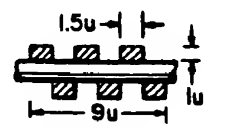


FIG. 3b
PRIOR ART

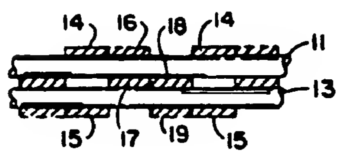


FIG. 2

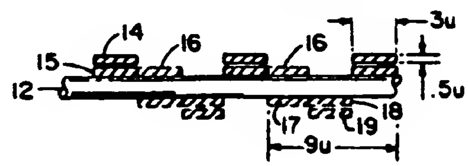


FIG. 3a

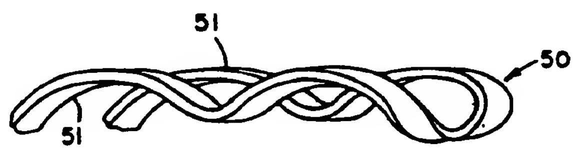


FIG. 5a
(PRIOR ART)

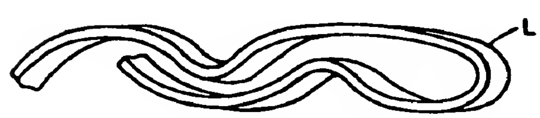


FIG. 5b

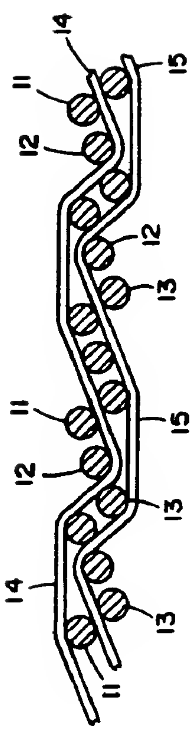


FIG. 4a

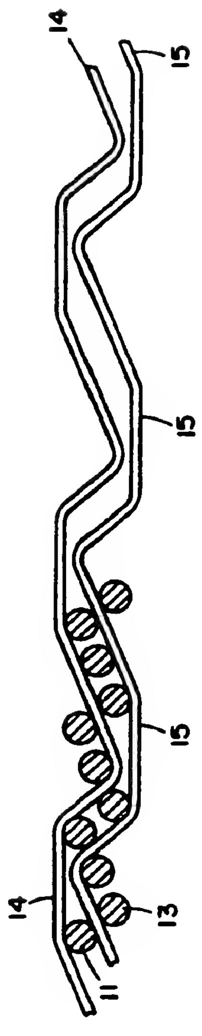


FIG. 4b

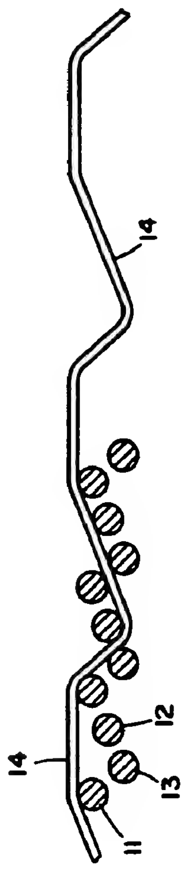


FIG. 4c

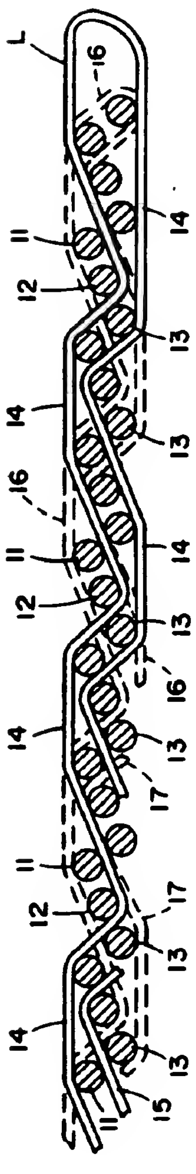


FIG. 4d

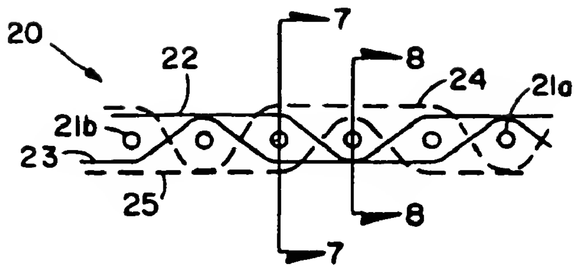


FIG. 6

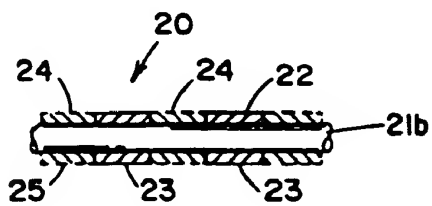


FIG. 7

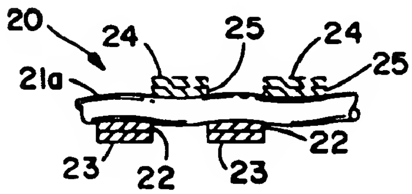


FIG. 8

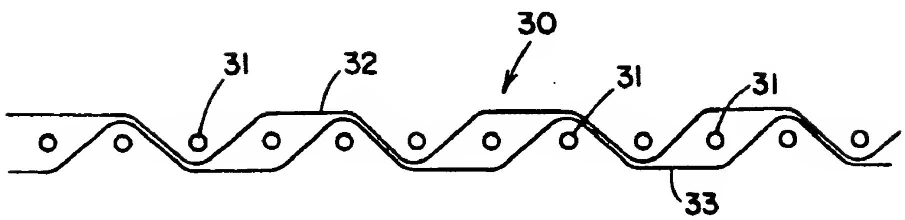
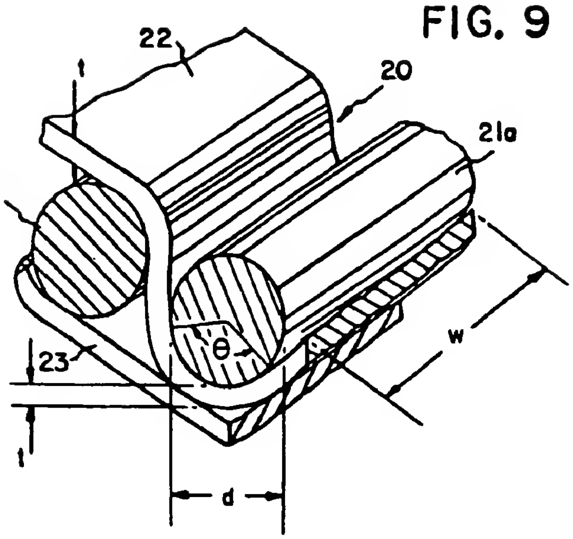


FIG. 12

FIG. 9



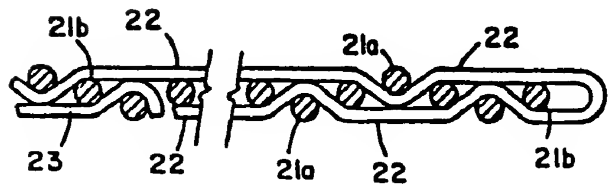
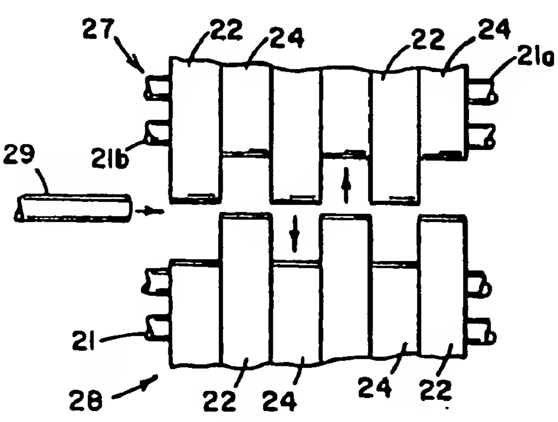


FIG. 10

FIG. 11



WEST

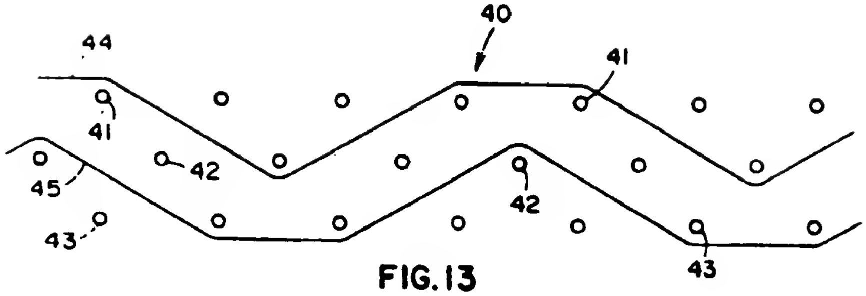


FIG.13

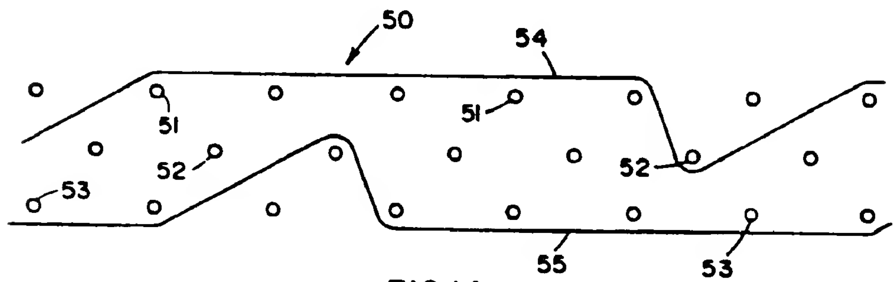


FIG.14

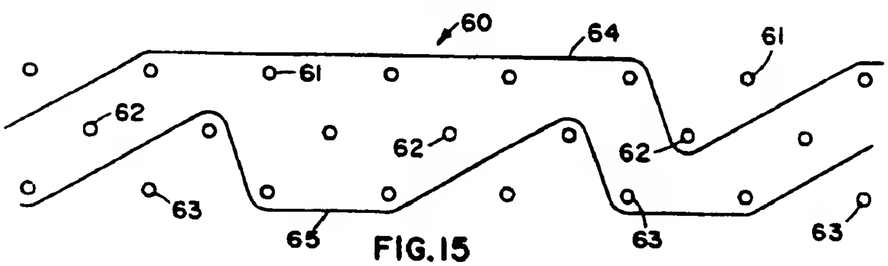


FIG.15

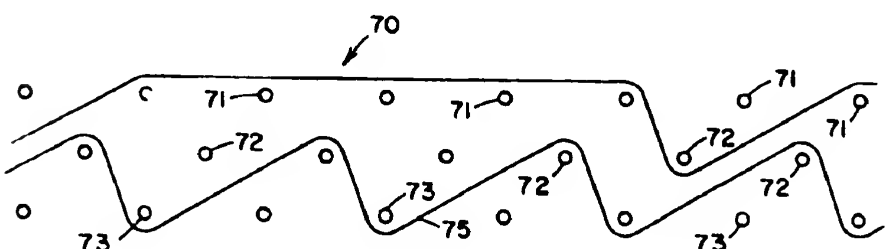


FIG.16

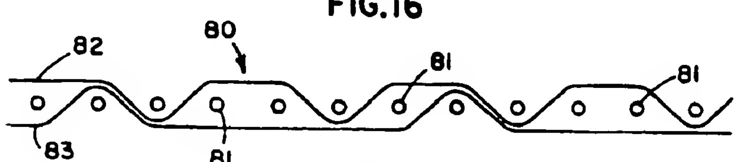


FIG.17

WEST

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 10 3975

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
E	WO-A-91 04374 (JWI) * the whole document * ---	1,4	D21F1/00
D,A	US-A-4 290 209 (BUCHANAN ET AL) * the whole document * ---	1,2,4	
A	EP-A-0 211 426 (WANGNER) * the whole document * ---	5	
A	EP-A-0 144 592 (NIPPON FILCON CO.) * the whole document * -----	3	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

D21F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 June 1994	De Rijck, F

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

T : theory or principle underlying the invention
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